

State of Florida
Department of Transportation



**QUALITY ASSURANCE FOR MOBILE
RETROREFLECTIVITY UNITS**



FDOT Office
State Materials Office

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INTRODUCTION

As part of the Pavement Marking Management System, the Florida Department of Transportation (FDOT) has developed a Quality Assurance document for the Mobile Retroreflectivity Unit (MRU) equipment and operators. This document establishes a series of laboratory and field tests at the State Materials Office (SMO) located in Gainesville, Florida. The laboratory test consists of a series of experiments that are conducted in a controlled environment (i.e., FDOT's MRU calibration bay), and field evaluations will be conducted on a series of roadways in Alachua County, Florida, with various pavement markings and pavement types. This document also establishes data acceptance criteria for project and network levels to evaluate stripes surveyed by the Contractor to ensure reliable retroreflectivity data statewide. Table 1 are the laboratory and field testing requirements to be followed by MRU Contractor for collecting data for the Pavement Marking Management System. A detailed description of each test and data acceptance criteria is provided in the following sections.

Table 1. Summary Requirements of Laboratory and Field Quality Assurance Test

Type of Test		Key Item Check	Required Criteria	Testing Frequency
Setup and Visual Inspection		Distance	1) Accurate 30 meter geometry; 2) $\geq 40"$ lateral data collection area; 3) $\leq 40"$ in the longitudinal variation	65 days
Verification Test		R _L	$\pm 15.0\%$ of certified R _L values	65 days
Background Noise Test		R _L	$\pm 5.0\%$ of calibration panel	365 days
Equipment Dynamics	Lateral	R _L	$\pm 10.0\%$ from the center position	65 days
	Longitudinal	R _L	Not Applicable	65 days
DMI and GPS Accuracy	DMI	Distance	$\pm 0.1\%$ of calibration section	35 days
	GPS	Position	± 10.0 feet of a calibrated position	35 days
Precision Test		R _L	$\pm 10.0\%$ for repeatability and $\pm 15.0\%$ for reproducibility	65 days
Reflectivity Stability with Speed Test		R _L	$\pm 10.0\%$ difference from two tests running at 35 mph and 55 mph	365 days
Reflectivity Stability with Temperature Test		R _L	$\pm 10.0\%$ difference from two tests running at two different temperatures within the day	365 days
Operational Competency		R _L	± 75 R _L for the running mile comparisons between FDOT and the Contractor	365 days

MRU equipment must be operated in accordance to Florida Test Method for Measuring Retroreflectivity of Pavement Marking Materials Using a Mobile Retroreflectivity Unit (FM5-600) and all retroreflectivity data is required in *FDOT Form 675-060-05*.

LABORATORY TESTING

The following tests will be conducted to verify the performance of the MRU, data collection software, and operator(s) in a controlled environment:

- Equipment and Operator(s) Identification
- Setup and Visual Inspection
- Verification Testing
- Background Testing
- Equipment Dynamics

For these tests, the equipment must be warmed up to manufacturer recommendation and MRU calibrated or a system check performed prior to the quality assurance testing. A calibration or system check file, at time of file output, must be submitted.

Equipment and Operator(s) Identification

Equipment and operator(s) identification is necessary to document the MRU (retroreflective unit and vehicle), data collection software (computer and software), and operator/team conducting the retroreflective testing. Each of these components have a specific timeframe in which they remain valid. Anytime a component is altered or replaced, the Contractor must inform FDOT and verify that all quality assurance criteria are satisfied. The above equipment and operator(s) identification must be recorded once every 65 days or as considered necessary.

Setup and Visual Inspection

Setup and visual inspection is critical to ensure the equipment is operational by verifying all brackets, mounts, and bolts are tight and mounted securely around the exterior and interior of the equipment before calibration and routine operation. The retroreflectometer window must be inspected to make sure it is clean and clear of damage and/or debris. It is also, good practice to inspect the optics to ensure they are clean and clear of damage and/or debris.

The MRU certified calibration standard(s) must be inspected for damage, wear, and ensure it has been verified by a Department approved facility using photometric range equipment within a year prior to its use. The MRU operator will setup the calibration procedure. This process will be inspected by FDOT personnel to assure accuracy and proper 30 meter geometry in accordance with ASTM E-1710. The retroreflectometer laser power intensity will be measured and recorded. The MRU must be capable of measuring a stripe at a minimum of 20.0 inches on either side of the center position at the proper geometry while the longitudinal variation should not exceed 40.0 inches. The above visual inspection of the MRU must be conducted once every 65 days or as deemed necessary.

The MRU can be calibrated or a system check performed again if needed before

continuing the quality assurance testing. The calibration or system check file, at time of file output, must be submitted.

Verification Testing

In order to determine if the accuracy of the R_L values measured using the MRU are comparable to those from a Department approved photometric range system, handheld retroreflector and MRU, a combination of pavement marking samples with R_L values ranging between 100 and 1,000 mcd/m²/lux will be tested. A stripe will be placed in front of the MRU and centered at proper geometry. A test shall be initiated and as the reading has stabilized, the R_L value will be recorded. The R_L of eight or more samples including ceramic, vinyl, and pavement markings materials will be measured with the MRU, one at a time. The pooled results of the MRU from the samples must not differ by more than $\pm 15.0\%$ of the certified R_L values. The background will be monitored during this test to see if different stripes affect the background reading. The accuracy tests must be conducted once every 65 days or as deemed necessary.

Background Testing

Background testing is performed to ensure that environmental effects and other reflective materials are not influencing the R_L values. While measuring a stripe in the single stripe type mode, a material will be placed in front of the MRU and centered at proper geometry. If needed, thresholds or filters should be applied at this time so that the MRU can collect accurate measurements and not influenced by background. A test shall be initiated and as the reading has stabilized, the R_L value and background reading will be recorded. The test will be stopped and a material will then be placed down to change the background reading. A new test will be initiated, and a new R_L value and background will be recorded. The test will be stopped, material removed, and a second retroreflective material with lower R_L value will be placed to the side of the stripe. A new test will be initiated, and a new R_L value and background will be recorded. The R_L of the stripe should not vary by more than $\pm 5.0\%$ for these two tests. The test will be stopped and lastly, a raised pavement marking (RPM) with higher R_L value will be placed to the side of the stripe. Another test will be initiated, and a R_L value and background will be recorded. The R_L of the calibration panel should not vary by more than $\pm 5.0\%$. The background testing must be conducted once every 365 days or as deemed necessary.

Equipment Dynamics

Two equipment tests will be performed to simulate lateral and longitudinal dynamics to ensure both the MRU is capable of collecting at the various roadway geometries and the consistency of the retroreflectivity (R_L) value as these geometries change.

Lateral Dynamics

Lateral Dynamics is a test performed to verify the MRU is within tolerance to allow minimum vehicle wander and maintain the R_L value as the vehicle changes horizontal position across the pavement. A stripe will be placed in front of the MRU and centered at proper geometry. A test shall be initiated and as the reading has stabilized, the R_L value will be recorded. The test will be stopped and the stripe shall be repositioned horizontally.

A new test will be initiated, and a new R_L value will be recorded. This procedure will take place several times moving the stripe in increments of 5.0 inches across the 40.0 inch minimum lateral data collection area. At all positions along the horizontal path, the R_L value shall not differ by more than $\pm 10.0\%$ from the center position. The lateral dynamics of the MRU must be tested once every 65 days or as deemed necessary.

Longitudinal Dynamics

Longitudinal Dynamics is a test conducted to verify the vertical geometries of the stripe in order to simulate data collection while traveling along small vertical curves. A stripe will be placed in front of the MRU and centered at proper meter geometry. A test shall be initiated and as the reading has stabilized, the R_L value will be recorded. After a measurement has been taken, small vertical spacers will be placed below the front tires. The stripe will be repositioned until a R_L value can be recorded and a new measurement will be taken. The displacement of the stripe from the original position will also be recorded. Vertical spacers will then be removed from the front tires and placed below the rear tires with the stripe repositioned until a R_L value can be recorded and another measurement will be taken. Again, the displacement of the stripe from the original position will be recorded. The longitudinal dynamic results will be recorded but no criteria requirements enforced. The longitudinal dynamics of the MRU must be tested once every 65 days or as deemed necessary.

FIELD TESTING

The following tests will be conducted to verify the performance of the MRU, data collection software, and operator(s) in a field environment:

- Distance Measuring Instrument and Global Positioning System Accuracy
- Precision Testing
- Retroreflective Stability with Speed Test
- Retroreflective Stability with Temperature Test
- Operational Competency Test

For these tests, the MRU will be mounted on the passenger side of the vehicle. The MRU can be calibrated or a system check performed again if needed before continuing the field testing. The calibration or system check file, at time of file output, must be submitted.

Distance Measuring Instrument and Global Positioning System Accuracy

The MRU must be equipped with a distance measuring instrument (DMI) or a Global Positioning System (GPS) coordinates to measure the distance traveled by the vehicle and location. The FDOT SMO designated a site to verify the precision of the MRU DMI and GPS. The DMI distance must be within ± 5.280 (0.1%) feet when measuring a 1.0 mile section of roadway and GPS must be within an instantaneous horizontal positioning accuracy of ± 10.0 feet or better. The DMI must be calibrated and GPS verified on a 35 day basis or as deemed necessary at locations designated by FDOT. Additionally, a DMI recalibration must be performed anytime tires are changed, rotated, or air pressure is adjusted.

Precision Testing

To achieve repeatable and reproducible measurements between different MRUs, the FDOT SMO designated five field sites to verify the precision of the MRU. The test sections consist of broken (with RPMs) and solid pavement markings. The average pavement marking retroreflectivity for the test sections ranges from 100 to 800 mcd/m²/lux. These test sections are located in close proximity to the SMO. The beginning and ending locations of these 1.0 mile sections are clearly marked with tape.

The Contractor's MRU will perform three repeat runs on each test section at speeds of 55 MPH while being followed by a FDOT MRU. The pooled R_L results of the contractor's MRU from the five test sections must not differ by more than $\pm 10.0\%$ for repeatability and $\pm 15.0\%$ for reproducibility when compared to FDOT's MRU data. This precision test must be conducted once every 65 days or as deemed necessary.

Retroreflective Stability with Speed Test

MRU testing is conducted up to highway speeds so it is important to verify the MRU results are not affected by vehicle speed. To verify this, one section of roadway designated by FDOT shall be tested at 35 and 55 mph. The pooled R_L results from the two tests should not differ by more than $\pm 10.0\%$. This test shall be conducted once every 365 days or as deemed necessary.

Retroreflective Stability with Temperature Test

The MRU uses advanced optic and electronic devices known to be sensitive to temperature changes. Temperature may affect the R_L values if not properly addressed. This test is conducted to determine the long term R_L stability. Two separate tests will be conducted throughout the series of the field testing to verify the effects of ambient temperature on the MRU measurements. Additional MRU calibrations will not be allowed between the two tests. The pooled R_L results from the two tests should not differ by more than $\pm 10.0\%$. This test shall be conducted once every 365 days or as deemed necessary.

Operational Competency Test

To ensure the Contractors MRU Operator(s) can safely and accurately operate the MRU, the FDOT SMO designated five field sites to verify the operator(s) ability to navigate the roadway with the MRU. These field tests will be conducted to evaluate the following factors:

- Proper use of event codes such as pavement changes, bridge, turn lanes, etc.
- Driver competency (e.g., vehicle wander, route planning)
- Proper identification of stripes to meet the FDOT striping nomenclature
- Ability to set R_L thresholds for the Raised Pavement Markings (RPM)
- Proper handling of MRU during acceleration, braking, and stopping

For these tests, the MRU will be mounted on the driver side of the vehicle. The equipment must be warmed up to manufacturer recommendation and MRU calibrated or a system check performed prior to the operator competency testing. A calibration or system check

file, at time of file output, must be submitted. These test sections are located in close proximity to the SMO. The FDOT will provide detailed roadway information for 5 sites including beginning and ending locations. The tests shall be conducted on roadways with various pavement types and markings selected by FDOT to include the following:

- Stripe colors - Yellow and white
- Stripe patterns - Single solid, single skip, double solid, left solid/right skip, left skip/right solid, and edge line
- Stripe types - Thermoplastic, paint, tape, and audible
- Various ranges of retroreflectivity
- Pavement surface - Open and dense graded asphalt surfaces and rigid pavement surfaces
- Pavement colors – Light, medium, and dark (for different levels of background noise)

The Contractor's MRU will perform one run on each test section at highway speeds while being followed by a FDOT MRU. The results of the contractor's MRU from the five test sections must meet the criteria described below in the Project Level Quality Assurance. These field tests shall be conducted once every 365 days or as deemed necessary.

DATA ACCEPTANCE

The FDOT conducts independent Quality Assurance sampling of the stripes evaluated by the Contractor to ensure that the retroreflectivity data provided by the Contractor is reliable. The following data acceptance criteria will be applied to Contractor data to verify the performance of the MRU, data collection software, and operator(s) in the field:

- Project Level Quality Assurance
- Network Level Quality Assurance

FDOT will conduct comparison analysis on received data to ensure that it meets the required acceptance criteria. For these tests, the MRU may be mounted on either side of the vehicle. Calibration or system check file, must be submitted upon request.

Project Level Quality Assurance Testing

FDOT will randomly sample Contractor' surveyed miles, for verification purposes. The Contractor's data is compared to the FDOT data on a running mile average at 0.1 mile interval basis. Any running mile comparisons that disagree by more than $\pm 75 R_L$ must be retested by the Contractor. In addition, if the comparisons disagree for more than 30% of any roadway, the entire roadway must be retested. If the Contractor's retest data compares to the FDOT, it is accepted. If not, the Contractor's data will be evaluated at the Department's discretion on a case by case basis for data acceptance.

Network Level Quality Assurance Testing

Network Level Quality Assurance Testing is a two-step process. FDOT will randomly sample a minimum of 20% of all Contractor' surveyed miles, typically on a weekly basis, for

verification purposes. This sampling must consist of at least 20 miles. The comparison will be based on a running mile average at 0.1 mile intervals.

Step 1 (Accept or Reject a Week of Data) - If the running mile comparisons (FDOT and Contractor) agree within $\pm 95 R_L$ for more than 70% of the miles surveyed, the network level data is accepted. If not, the Contractor data is rejected and the Contractor must then resurvey 100% of the previous week mileage surveyed.

Step 2 (Verification of Data) - Once the data meets the Step 1 criteria, the following requirements are applied. The Contractor's data is compared to the FDOT data on a running mile average at 0.1 mile interval basis. Any running mile comparisons that disagree by more than $\pm 75 R_L$ must be retested by the Contractor. In addition, if the comparisons disagree for more than 30% of any roadway, the entire roadway must be retested. If the Contractor's retest data compares to the FDOT, it is accepted. If not, the Contractor's data will be evaluated at the Department's discretion on a case by case basis for data acceptance.

QUALITY ASSURANCE REQUIREMENTS

Prior to providing MRU services to FDOT, the Contractor must demonstrate that their MRU and operator(s) satisfy the laboratory and field quality assurance criteria described above. For times of dispute, the Department equipment will be considered as reference. In order to continue providing MRU services, the Contractor must conduct the quality assurance tests at the frequency designated for each respective test. Anytime a quality assurance criterion is not met, the Contractor must inform FDOT and take remedial action. The Contractor must also inform FDOT after remedial action has been implemented and again demonstrate that all quality assurance criteria are satisfied. The quality assurance tests that need to be repeated shall be determined by FDOT after reviewing the problem and the remedial action taken by the Contractor. After the laboratory and field quality assurance testing is completed, the FDOT will inform the Contractor of the results. Documents will be provided to the Contractor that indicates the MRU (retroreflective unit, computer, software, and the vehicle) and operator/team satisfy all of the quality assurance criteria for a time period provided on the document. The FDOT will also conduct independent Quality Assurance sampling of the stripes evaluated by the Contractor to ensure that the retroreflectivity data provided by the Contractor is reliable. Comparison analysis on project and network levels will be conducted on received data to accept Contractor data.



Mobile Retroreflectivity Unit

Quality Assurance Checklist

MRU No# _____ Test Date: _____

Vehicle, Equipment and Operator(s) Identification				
Operator 1	Name: _____			
Operator 2	Name: _____			
Vehicle	Year: _____	Make: _____	Model: _____	Tag #: _____
Laser Identification	Make: _____	Model: _____	Serial Number: _____	
Calibration Panel 1	ID: _____	RL Value: _____	Calibration Date: _____	
Calibration Panel 2	ID: _____	RL Value: _____	Calibration Date: _____	
Software	Developer: _____		Software Version: _____	

Laboratory Tests		Unsatisfactory	Pass	Expires
1	Brackets, mounts, and bolts are tight and mounted securely			
2	Windows are clean and clear of damage and/or debris			
3	Calibration panel(s) free of damage, wear, and certified within a year			
4	Calibration setup and testing geometry conforms to ASTM E1710			
5	Laser power intensity is stable			
6	Laser profile capable of $\pm 20''$ from center and within 40'' longitudinally			
7	Verification of the various test panels within $\pm 15\%$			
8	Background does not influence RL values more than $\pm 5\%$			
9	Lateral dynamics within $\pm 10\%$ tolerance (allows for vehicle wander)			
10	Longitudinal dynamics for roadway inclines & declines			
Field Tests		Unsatisfactory	Pass	Expires
11	Distance Measuring Instrument within ± 5.280 (0.1%)			
12	Global Position System within $\pm 20\text{ft}$			
13	Precision in terms of repeatability within $\pm 10\%$			
14	Precision in terms of reproducibility within $\pm 15\%$			
15	Retroreflective stability (change in speed) within $\pm 10\%$			
16	Retroreflective stability (change in temperature) within $\pm 10\%$			
17	Operational competency (operator(s) demonstrates ability to use MRU)			

Defects Found: _____ _____ _____ _____ _____	Corrective Actions: _____ _____ _____ _____ _____
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Inspection completed by: _____ Date: _____

Vendor signature: _____ Date: _____

Supervisor signature: _____ Date: _____